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Are Returns to Investment Lower for the Poor?

Human and Physical Capital Interactions in Rural Vietnam

Dominique van de Walle

Unless disparities in education are addressed, market-oriented reforms will generate inequitable agricultural growth in Vietnam.

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Summary findings

If the marginal gains from investment in physical capital depend positively on knowledge, but a household cannot hire skilled labor to compensate for low skills, then even if it has access to credit the household will achieve lower returns than an educated household.

If, as is common, the income-poor are less educated because of failures in the credit market and because they live in areas where there is less access to schooling, then the poor will also have lower returns on investments.

Van de Walle tests this argument for the case of irrigation infrastructure in Vietnam.

She asks how a household's education level and demographic characteristics influence the gains to household income from irrigating previously unirrigated land.

The net marginal benefit of irrigation increases strongly with the education of a household.

The results suggest that unless disparities in education are addressed, market-oriented reforms will generate inequitable agricultural growth in Vietnam.

This paper—a product of Public Economics, Development Research Group—is part of a larger effort in the group to understand the determinants of poverty and the policy implications. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Hedy Sladovich, room MC2-609, telephone 202-473-7698, fax 202-522-1154, email address hsladovich@worldbank.org. Policy Research Working Papers are also posted on the Web at www.worldbank.org/research/workingpapers. The author may be contacted at dvandewalle@worldbank.org. August 2000. (28 pages)

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1. Introduction

It is often argued that the poor, and poorly educated, have less access to credit for financing investment. This is known to have important implications for understanding the interaction between distribution and growth.[1] The more poor (and hence credit constrained) people there are, the lower the rate of growth, and the more likely poverty will persist. Relaxing credit market constraints is then seen to be key to equitable investment.

However, could it also be that the poor, and poorly educated, face lower rates of return to given investments? This may reflect other market failures, such as in land and labor markets. Credit market failure may then be only part of the problem of persistent poverty. The question also has bearing on the likely quality of the future growth process. With market-oriented reforms, resources will tend to flow to households with higher rates of return to investment. If these are the non-poor, then an inequitable growth process will result. By contrast, if in fact the poor get higher returns, growth promoting reforms will tend to be inequality reducing.

An argument as to why we might expect the poor to obtain lower returns to investment can be sketched as follows. In poor, rural, developing economies—and especially those undergoing transition to a market economy—farm-households appear often to be severely constrained in pursuing investment opportunities. Underdeveloped or missing labor markets are also common in such settings. A poorly educated family living in a poor remote rural area cannot easily hire the services of a well educated worker, who could allow the family to get the most out of new technology, even when credit is available to finance the investments required. Typically such economies are also characterized by considerable disparities in educational attainments, correlated with poverty. This may well reflect credit market failures, but it also arises from the cost of geographic mobility and inequality in access to schools. Both schooling levels and market development are likely to also vary regionally.

[1] For a survey of the theoretical arguments, see Aghion et al. (1999).

In settings such as these, returns to physical investments will naturally depend on human capital endowments at the family level. More educated households are more likely to draw advantage from opportunities afforded them through investments. By this view, what distinguishes the poor, rural, transition economy is the fact that even if a household could afford to hire skilled labor to make up for its lack of education, it cannot because the market does not exist. Under the circumstances, one can imagine a situation whereby educational inequalities and labor market failures interact to create inequalities in the returns to investments in physical capital—whether public or private. Moreover, lower returns will be concentrated primarily among the poor, and poorly educated.

This paper tests the above argument. The paper focuses on the case of irrigation investments in rural Vietnam. Household survey data are used to conduct a detailed investigation of the marginal gains from irrigation and how they are affected by levels of human capital and other household level factors. The paper asks: Do education levels raise farm profits? Through what means? Apart from a direct effect, does education also reinforce the effect of the key productive input of irrigation? Do returns to irrigation vary between rich and poor households. And, if so, how much of the variation can be explained by differences in education attainments? Do better educated households have higher gains from physical infrastructure investments?

A recent analysis of the changes in poverty and inequality between the early and late 1990s in Vietnam documents increasing inequality (Glewwe et al. 2000). It also finds that the returns to education have increased and that a bigger share of inequality is attributable to education disparities in the later period. A further aim of the present paper is to search for the root of these changes in the situation of the early 1990s. One possible factor could be differences in returns to investments that could in turn lead to an inequitable growth process.

A vast literature exists on the returns to human capital, and to education in particular. Links have been established between education and numerous outcomes—including productivity (both market and non-market), wages and earnings, adoption of new technologies, one's own health, nutrition and fertility, and others', including one's children's health, nutrition, fertility and schooling (for an overview and references, see Strauss and Thomas 1995). Much attention has been devoted to complementarities between different types of human capital. For example, one issue has been how better nutrition and health interact with schooling to create better educational outcomes.

Another strand of research has studied the links between physical infrastructure, productivity and household welfare (surveys can be found in Jimenez 1995, and Behrman 1990). Some of these studies focus on how infrastructure improves social indicators—for example, how safe water supply affects health outcomes or how electricity can have positive impacts on education indicators through enabling children to study after daylight hours.

The returns to education were long measured through wage or earnings regressions with the focus naturally on labor market outcomes and, in poor rural settings, the non-farm informal sector. Jamison and Lau (1982) were among the first to focus on the agriculturally self-employed and to identify non-wage effects of education on agricultural productivity. In particular, they focused on the effects of schooling on agricultural efficiency. Part of that effect was found to be transmitted through education's influence on the choice of production techniques, such as through increasing the willingness to adopt new technologies. Jamison and Lau estimate production functions that allow for interaction effects between education and the availability of extension services, and find some evidence that agricultural extension enhances the effect of education on agricultural productivity. They do not examine interactions between education and other inputs, however.

There is also evidence that education promotes pro-poor non-farm economic development. In state-level time series data for India, Ravallion and Datt (1999) find that states with initially higher rural literacy rates experienced more pro-poor growth processes, notably in the non-farm sectors.

In the context of this literature, the contribution of the present paper is to study the interactions between the returns to investment and education and other household characteristics, including demographics. Does the type of interaction Jamison and Lau (1982) identify between education and extension service availability also hold for irrigation? In short, are there complementarities between human capital and physical capital?

Why should we care about these questions? One can think of two reasons. The first has to do with a longstanding debate in development policy—the case for and against multi-sectoral integrated approaches to development projects. For example, should traditional infrastructure projects be combined with education projects? Should credit be combined with education (as in the "non-lending" services supplied by some credit NGOs, such as Grameen Bank in Bangladesh)? The second stems from the fact that we may be concerned about distributional impacts. Much evidence indicates that irrigation works are often cornered by wealthier, larger farmers. In most poor countries, such households will also be better educated. If the returns to irrigation investments are indeed enhanced by education, inequality could be compounded and long-term pro-poor growth compromised, without complementary targeted education interventions. Finally, under this scenario, loosening credit market constraints will not be sufficient for ensuring equitable growth.

Section 2 gives an overview of the economic environment in rural Vietnam at the time of data collection in 1992/3 and a description of the data. Section 3 describes the hypothesis to be tested and the method, whereby farm household crop incomes are modeled as functions of household and community characteristics. The results are found in Section 4. An assessment is made of the determinants of the marginal returns to irrigated land and the role of education. The final section concludes.

2. Setting and Data

In 1988, Vietnam disbanded its agricultural cooperatives, re-instated family-based production and re-allocated land to farm-households for long-term use. However, land continued to be owned by the State, and hence, land markets to be illegal. The reforms resulted in rising incomes for many rural households. However, regional disparities in the speed and degree of market penetration, and reductions in public provisioning and financing of social services combined with increased reliance on household participation, dampened average income gains in rural areas (Glewwe and Litvack 1998).

At the time of the data used here, 1992/93, a majority of rural Vietnamese households derived the bulk of their livelihoods from subsistence farming (van de Walle 2000). Opportunities for off-farm work were thin in most areas. According to the 1992/3 Vietnam Living Standards Survey, unskilled wage work was available at some time during the year in the communes of only 65 percent of the rural population, and varying from 50 percent of the poor to 74 percent of the non-poor.[2] A commercial enterprise was present within ten kilometers of the communes of no more than 44 percent of households (40 percent of the poor, 50 of the non-poor). Forty-six percent of households relied solely on farming (48% in the North, 40% in the South, 50% of the poor and 40% of the non-poor); 20 percent combined farming with self-employment income; 19 percent combined farm and wage work, and 7 percent had all three sources of income. In general, markets in the South were more developed reflecting its different past.

Why has the rural labor market generally not worked better? The answer appears to be found in a combination of factors. The continuing legacy of the planned economy and a historical emphasis on the ideal of the self-subsistence family farm play a part. Poverty, poor infrastructure, limited access to credit, a lack of mobility and geographical disparities are other contributory factors. For example, these factors make it hard for a poor area to attract skilled or educated workers and hire them. They also prevent an efficient matching of labor supply and demand.

The market reforms and freedom from the cooperatives appear to have had little effect on mobility. Until 1986, mobility had been severely restricted through the

[2] The poor are those with household per capita expenditures below a poverty line determined by the cost-of-basic-needs method and detailed in Dollar and Glewwe (1998).

distribution of subsidies for essential goods being tied to residency (UNDP 1998). Although the subsidy system was discontinued, mobility continued de facto to be constrained by the fact that, together with access to social services, major transactions, such as to do with land, housing, and credit remained closely tied to one's residency permit. The difficulties entailed in establishing new residency, the poor state of transport and communications infrastructure, the absence of a land market, and the decentralized nature of the safety-net system all contributed to effectively discouraging mobility (van de Walle 1999). Typically, a rural household's only risk-insurance is its access to the community-based safety-net, and its most valuable non-labor asset is its land—whose continued allocation is subject to residency. These facts make migration a risky undertaking (UNDP 1998).[3]

There is a strong regional dimension to the above factors—poverty varies across provinces and districts and is more pronounced in places that are more remote from markets and cities (Minot 1998). These same places have the least non-farm income earning opportunities, the least developed infrastructure and generally poorer access and quality of schooling.

Communism's legacy is a relatively well educated and healthy population, particularly in the North where public health and education efforts began much earlier. But again, there are important regional disparities and a pronounced correlation between education levels and poverty. Table 1 presents mean years of primary and post-primary schooling for household heads and other household adult members by poverty status and region. The worse attainments and higher inequality in attainments in the South relative to the North come out clearly. Regional inequalities in access to schooling and school inputs and quality have been documented by many including World Bank (1999).

Irrigation and water control play a critical role in the production process in Vietnam and the success of agriculture at the local level. In 1992/3, only 21 percent of the total land

[3] Similarly, Jalan and Ravallion (1999) find that migration is not risk reducing in rural China (in provinces bordering Vietnam).

area was under cultivation and about half of that was irrigated (Vu and Taillard 1993). Approximately the same percentage of agricultural annual crop land was irrigated.[4] As in other infrastructure areas, there had been negligible capital investment for decades and existing networks were often not functioning. Household annual crop land allocations dated back to 1988 and had changed little since. In the North, assignments were made according to household size or labor capacity, and allowing for land heterogeneity including quality and water access (Barker 1994). Allocations in the South were generally less equitable, reverting largely to the pre-reunification status quo.

The analysis uses the country's first nationally representative household consumption sample survey, the1992/3 Vietnam Living Standards Survey (VNLSS). The VNLSS gathers detailed information on consumption expenditures, incomes and many facets of living standards for 4800 households, of which 3840 are rural. There are modules that focus on land assets, agricultural production and farm incomes. The VNLSS enforces a broad definition of irrigation. Land is recorded as irrigated if it benefits from a water control system geared to averting drought or excess flooding. The household survey is complemented by a community level questionnaire that collects details on socio-economic characteristics including access to social and physical infrastructure facilities for all communes in which surveyed households reside. By the standards of household surveys in poor countries, the VNLSS is considered of high quality.[5]

Real household consumption expenditures per capita are used as the welfare indicator. The deflator is the ratio of region specific poverty lines to the national poverty line.

[4] In addition to annual crop land, households derive agricultural incomes from perennial land (tree crops), forest land, water surface land (for raising water products) and 'other land': vacant lots and bald hills (managed by the household but not cultivated for at least a year); burnt and fallow land, road, dike, and river banks, etc. The paper focuses on annual crop land.

[5] A detailed description of the survey questionnaires and data is given in Glewwe (1994).

3. Determinants of Crop Incomes in Vietnam

3.1 The Hypothesis to be Tested

In a world of perfect markets, marginal products of capital will be equalized across all farm-households. In equilibrium, the net gain to farm profits from investing in irrigation (marginal value product of irrigating unirrigated land minus rental price of the capital inputs) will have been driven down to zero for all farm-households. This no longer holds with capital market imperfections, such that the farm-household is constrained by its current capital stock. The net gains from investment will then vary.

Suppose also that investments require knowledge inputs that raise the marginal product of capital. If the farm-household is similarly constrained in its ability to hire these knowledge inputs then the higher its existing stock of knowledge, the higher will be the marginal gains to the farm-household from relaxing the constraint on its investment opportunities. The knowledge-poor will have lower returns from investment in irrigation.

Suppose that, in addition to these assumptions, richer households are better able to cover the costs of acquiring knowledge by sending their children to school, for example. The rich households may not have any better access to credit for this purpose, but they can substitute their higher personal wealth.

Together these assumptions imply that the poorer a farm-household is, the lower will be the rate of return it can expect from a given investment in irrigation, or any similar type of farm capital. The key testable implication of this hypothesis is found in how irrigation influences living standards in rural Vietnam, and how education and other variables influence that relationship. In particular, the paper aims to test for interaction effects between irrigation investment and human capital endowments at the household level.

3.2 *The Method of Testing*

To test the above hypothesis, the paper examines the determinants of net farm crop income. The size of the difference in marginal returns between irrigated and non-irrigated land determines the income gains from irrigating a unit of land. The profit function $\pi(p, L^N, L^I, z)$ gives the farm-household's maximum profit conditional on a vector of prices (p), amounts of non-irrigated (L^N) and irrigated (L^I) annual crop land, and a vector of other fixed factors (z). A wide range of variables are included in z to allow for constraints arising from market imperfections.

Profit is measured by farm crop income, net of variable costs.[6] For the j[th] household, the profit function is assumed to be:

$$\textbf{(1)} \qquad \pi_j = \pi(p(d_j), L_j^N, L_j^I, z_j) = \alpha + \beta_j^N L_j^N + \beta_j^I L_j^I + \gamma z_j + \delta d_j + \varepsilon_j$$

where (to allow interaction effects such that the marginal returns to irrigation vary across households):

$$\textbf{(2)} \qquad \beta_j^N = b_0^N + b_1^N d_j + b_2^N z_j + b_3^N L_j^N$$

and

$$\textbf{(3)} \qquad \beta_j^I = b_0^I + b_1^I d_j + b_2^I z_j + b_3^I L_j^I$$

The error term in (1) is assumed to be independently and identically normally distributed. The regression includes a full set of commune dummy variables (d in equation 1) that will pick up prices, spatial, cross-commune variations in other omitted or fixed factors such as

[6] Total revenue from agricultural production includes all crops evaluated at harvest prices (missing values are replaced by average community prices); the value of crop byproducts consumed or sold; land incomes and income from leasing out farm production equipment. Total production costs are subtracted. These include costs of hired labor, seeds and young plants, fertilizer, manure, insecticide, animal rental, transport, packaging and storage, equipment rental, repair and maintenance fees, fuel oil and electricity, an accounting depreciation charge for owned farming equipment (5%), land and other taxes and fees to cooperative or government. Transformation of home grown crops or livestock income are not included. The costs of household labor inputs on the family farm are also omitted. This is defensible if one is concerned solely with the impact of irrigation on family consumption (since the implicit payment for own-labor inputs is exactly matched by the receipts leaving consumption unchanged).

soil and schooling quality, and community level characteristics, including geographical and infrastructure variations. Prices are thus assumed to vary between but not within communes. These spatial effects are compressed into seven regional entities in their effects on marginal returns (d in equations 2 and 3).

Household level explanatory variables contained in z include household size and composition; gender of the household head; years of primary school education (0 to 5) and of any additional education of the household head; the same for other adult household members (aged over 17);[7] access to other types of agricultural land;[8] proportions of annual crop land in various forms of ownership;[9] the stock of savings, and dummy variables for urban residence and a household member's illness in the last year.[10] Table 2 provides variable descriptions and summary statistics.

As discussed in Section 2, land is not allocated by a market mechanism in Vietnam. Given virtually static land allocations since 1988 and negligible mobility, concerns about regressing outputs on inputs chosen by the household (and hence endogenous) do not arise in this setting with respect to land. The existence of irrigation in an area can also be reasonably treated as exogenous at the household level given that land allocation is pre-determined and the nature of irrigation technology entails that a single farmer will rarely be able to undertake the investment required on his own. The fact that there has been negligible expansion in irrigation since 1988 reinforces this argument.

[7] The education of school age children is omitted to avoid possible endogeneity problems. The latter could result if, households with unobserved factors contributing to higher farm profits are more likely to pull children out of school.

[8] See footnote 4.

[9] It may be important to distinguish between land ownership rights. In the survey (pre-the new land law of late 1993) land is defined as one of 5 types: i) Allocated: (North only) land from the cooperative's fund, distributed according to number of household workers. ii) Auctioned: (North) 5-10 % of the cooperative's land, reserved for bidding by households, more expensive, with a 3 to 5 year tenure depending on the region. iii) Long term use: the South's equivalent of allocated land. iv) Private: used by households as a garden area, often of lower quality, required no payment. v) Sharecropped or rented.

[10] In addition, dummy variables for the household head's ethnicity, age, religion, language, and whether born in present residence were found to be insignificant and to have no effect on the other regression coefficients.

Omitted variable bias is a potential concern, however. The commune level dummy variables will pick up omitted between-commune, but not omitted within commune variance—such as in land or soil quality. If, for example, better parcels of land have already been irrigated, the regressions will overestimate the returns to expanding irrigation to the remaining parcels. To test for this possibility, the regressions were estimated with crop land entered separately as irrigated land of poor, medium and good quality and similarly for non-irrigated land. These variables were insignificant and no signs of bias due to differences in land quality, at least as measured in the survey, were found. Annual crop land is thus entered simply as irrigated and non-irrigated land. Omitted variable bias could be more of a problem in the South, where salinity and acidity problems are common for irrigated land in the Mekong delta, though not identified in the survey.

Given the education system's high degree of decentralization to the local (commune) level, education quality is likely to vary across communes but much less so within communes. Variations should thus be captured by the commune dummies. A further potential source of bias is if years of education are highly correlated with innate ability or family background, and thus proxy for unobserved endowments. The latter could then determine how many years are spent in school but also labor productivity. Inability to control for innate ability is a common problem in estimating education impacts. However, there is too much variance in both the access to schooling and its quality in Vietnam for this to be a plausible and complete explanation for the results discussed below. Given existing spatial differences in access, many perfectly able people will not benefit from schooling. Thus, as a result of supply side factors, it can be argued that years of education are unlikely to be well correlated with ability.

OLS is used on the sample of 3049 farm-households (including some urban farm-households) surveyed in the VNLSS, as described in Section 2, and for which the data are complete.

4. Results

4.1 The Regressions

Table 3 reports results for two regressions: the 'unrestricted model' contains all variables, while the 'restricted' model is the outcome of pruning variables with t-ratios below 1 in the unrestricted model and following iterations. In an effort to make Table 3 more compact, variables with t-ratios below 1 and the commune dummies are not reported.[11] Table 4 presents the calculated total marginal effects and t-statistics of variables that enter the regression interacted with other variables, evaluated at mean points. Annual land, both irrigated and non-irrigated, and perennial land all have high significant positive overall effects on crop income. The impact of irrigated land is more than twice as large as that of non-irrigated land. There are also high returns to perennial land. Returns to other land types are lower and only water surface in the restricted model is statistically significant.

Education variables are found to have pronounced and significant positive impacts on crop income. In particular, one extra year of primary education for the head of household increases crop income by an amount equal to about eight percent of mean crop income. There are decreasing returns to the education of the household head, but not to that of other members. There is clearly no sign here that the returns to education are primarily captured through non-farm activities. Finally, larger households have higher crop incomes. This implies that family labor endowments matter in agricultural production probably because labor markets are underdeveloped. The marginal effects of demographic composition variables are not statistically significant.

The regression shows strong, though diminishing, impacts of annual crop land—both irrigated and non-irrigated—on crop income (Table 3). Household size matters, though composition effects are not of consequence independently of the interaction with land. Many of the interaction effects are significant and of interest. For example, household size appears important in its interactions with nearly all land variables (all are significant in the restricted model), as does the share of female adults. These effects are mostly positive and demonstrate the importance of family labor inputs, and particularly female ones.[12] They suggest a dependency on own household labor, and point to labor market imperfections and the inability of many households to hire labor in or out.

In contrast, interacting size and the female adult share with irrigated land, and the female adult share with non-irrigated land, results in a negative impact. A plausible interpretation seems to be that the market labor constraint does not bite as much for large irrigated holdings in the South. This fact drives the overall result. When the sample is partitioned across regions, the negative effect holds only in the South, and particularly in the Mekong delta (though it is clearly strong enough to influence estimation results for the national model). For households with larger amounts of irrigated land, family labor becomes less of a constraint. It is the way in which household labor influences crop income that is important here. If households could buy or sell as much labor time as required then one would not expect household demographics to be significant in the crop income equation. The fact that they are significant can then be taken as an implication of labor market failure. Family labor becomes an input to production but the extent to which this matters depends on how much market conditions apply to each household. The results indicate that family labor is generally a constraining factor in farm production in the North, but less so in the South and particularly less so for households with lots of irrigated land in the Mekong delta.[13] A test of the linear restriction that the overall influence of household size is zero when evaluated at mean sample values is not rejected for the South (though the number is positive), but is found to be positive and significant in the North. (The same is

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[11] Full regression details are available from the author.

[12] Women play a major role in agriculture in Vietnam. The VNLSS indicates that women averaged the equivalent of 182.5 eight hour days a year on the family farm and men 159.4 days.

[13] A number of factors lend support to this interpretation. Commune level wage data show that labor markets are better developed in the South. Both agricultural and unskilled non-agricultural wages are missing for a larger share of households in the North than in the South. Salinger (1993) corroborates the underdeveloped state of labor markets in North relative to South Vietnam. More so than elsewhere, the Mekong delta has large fully irrigated or unirrigated areas. van de Walle (1996) finds that irrigation increases labor input requirements. It may be surmised that labor markets are likely to have better developed in areas of the Mekong with large irrigated farms.

found for the female share.) Thus, the importance of the labor market constraint varies across households and from region to region.

Education is found to be of considerable importance to agricultural productivity. The primary schooling of the household head is important on its own and convex in its impact on crop incomes, implying increasing returns to schooling. Interaction effects between education variables and land are generally positive. Interestingly, the results imply that primary education interacts strongly with irrigated land to increase crop income while post-primary education does not.

Many of the 119 commune dummies are significant at the 5% significance level. There are also non-negligible spatial differences in the effects of both irrigated and non-irrigated land, and other land types. These effects are relative to land impacts on crop incomes in the South East (left out of the regression) and show expected signs and magnitudes.

4.2 Explaining the Marginal Returns to Irrigation

The regression results provide evidence of important synergies between household education and the returns to irrigation. A natural question is how much larger the effect of irrigation on crop incomes could be if education levels were higher?

The marginal effects on crop income of irrigated and non-irrigated land are calculated and presented in Table 5 under three education scenarios: i) all education variables are increased by one standard deviation of their value; ii) all primary education is increased (to 5 full years for the household head and by one standard deviation for all other adults); and iii) the household head's primary education is set to the maximum five years. The resulting net impacts can be compared to irrigation's baseline net marginal effect on crop income. Land's marginal effect is increased in all three cases, as is the net effect of irrigated land. The largest impact—a 36% boost in the net baseline effect—is achieved through increasing the primary schooling of all adults. Primary school completion for all heads results in a 10% increase, while an increase in all adults' education levels brings about a 19% increase in the baseline. Increased education influences the returns to both non-irrigated and irrigated land, but it has a larger relative effect on the latter.

The distribution of gains from an expansion of irrigation infrastructure, holding total cultivated land constant, will be determined by a number of factors. Clearly, the existing distribution of irrigated and non-irrigated land across households together with how the expansion is allocated across farms will play a key role. However, the above results on the determinants of crop incomes suggest that the influence of other household and community specific factors that enter the marginal benefit of irrigation function may also be considerable. That is the focus here.

The marginal gain from irrigating a unit of land is given by $\beta^I{}_j - \beta^N{}_j + b^I{}_3 L^I{}_j - b^N{}_3 L^N{}_j$ i.e., the difference between the derivatives with respect to irrigated and non-irrigated land, estimated using the parameter estimates in Table 3 applied to the household-specific values of the relevant variables. This will be called the marginal benefit function. The marginal benefit function thus shows the effect of each characteristic on the net marginal benefit of irrigation. It is given in Table 6, as evaluated at mean variable values. Of primary interest here are the strong and significant effects of the level of primary education on the marginal benefit from irrigation. This is true both of the head and other adult members of the household. Higher levels of education appear of much less consequence. The large, negative and significant impact of household size is also of note. Holding other factors constant, households best positioned to achieve the highest benefit from irrigation investments are those who have high levels of primary schooling and smaller household size. As one would expect, there are also some strong regional effects.

The mean net marginal benefit is 329 Dongs per year per square meter.[14] But, there is variation both across regions and the expenditure distribution. Figure 1 provides a scatter plot of the household level figures against per capita expenditures for the national sample, and for

[14] This differs from the baseline in table 5 because it excludes negative marginal benefits of irrigation found for some farms in the Mekong delta with large plots. This could be a problem with the model's performance in the South but it could also be that these farms are overirrigated. The paper now focuses on cases where returns to irrigation are positive.

North and South Vietnam separately. It also gives the line of best fit estimated non-parametrically. It can be seen that the marginal benefits have a tendency to increase with the welfare indicator. This pattern is somewhat more pronounced when the national picture is disaggregated into South and North. However, the gains are clearly progressive—declining as a share of the welfare indicator.

In estimating the marginal benefit of irrigating one unit of non-irrigated land, all household characteristics other than the amount of irrigated land are held constant and fixed at the mean of all variables. However, if other variables changed simultaneously, the marginal benefit of irrigation would also shift. As we have seen, education is found to be an important factor. As a policy variable, it is also of particular interest. The regression model's results suggest that the impact of an expansion of irrigation will be higher for households with greater human capital. Given the tendency for the total years of household education to be greater for higher expenditure groups in Vietnam as well as in the country's North, distributional and regional impacts can also be expected. The degree to which an extra quantity of education will shift irrigation benefits at the mean can be assessed using the marginal benefit function. It can help examine how much education levels contribute to differences in marginal benefits, and how much of the variation across households is explained by differences in education versus differences in other factors.

To explore these issues the paper asks how much the gains would vary if there were no differences in the education levels of adults across households. Marginal benefits are assessed under two policy simulations: 1) every household head has the maximum five years of primary education and 2) all adults complete primary schooling. Figure 2 gives a non-parametric assessment of the simulated and baseline household level marginal benefits plotted against per capita expenditures. The comparison of the gains at actual levels of education with the simulated amounts that would result if each household head had the maximum five years of primary education, or if all adults also had the five full years, clearly shows how markedly education levels can raise the returns to irrigation. This is evident along most of the expenditure distribution, though the impact is largest for the poorest and largely disappears for the richest. The results are most striking for the South, but the picture for the North is qualitatively similar.

Simulation 1 implies an average increase of only 0.43 years of education in the North and 0.82 in the South. Simulation 2 would require 2.53 and 3.87 additional school years in the North and South respectively. Under both policy simulations, extra education tends to go to the poor. Additional years of education therefore tend to equalize the marginal benefit conditional on expenditures. Despite policy 1 requiring a smaller increase in years of primary education on average, it achieves a greater response in the marginal benefits than policy 2. The elasticity of the marginal benefit of irrigation with respect to primary education is on average nearly two and a half times higher for a primary school completion policy targeted to household heads. The elasticities are also higher in the South, as are the proportionate increases in marginal benefits. This reflects the fact that education levels in the South are both lower and less equal than elsewhere in Vietnam.

The results thus suggest that a policy of primary education targeted to adults in Vietnam would have a substantial equalizing effect through its impact on the returns to irrigation investments. Conversely, the evidence supports the view that because of complementarities between education and investments in irrigation, the presence of inequalities in education that are correlated with levels of living result in lower returns to irrigation for the poor.

5. Conclusions

In modeling the determinants of crop incomes, the above analysis uncovers evidence of strong complementarities between the returns to irrigation and household education, particularly primary education in rural Vietnam. Simulated effects of increased education indicate that gains would accrue primarily to the poor and have a strong equalizing effect on the returns to irrigation investment. Demographics are also found to be important reflecting labor market imperfections. If one could buy and sell household level skills, these results would not be found in the data. This explains why the household stock of skills and education and its size and composition influence farm profits.

Lack of irrigation infrastructure is clearly only one constraint to reducing rural poverty in Vietnam. The quantity (in particular household size) and quality (education) of the family's human resources also matter. The full returns to irrigation will not be realized by the poor without concomitant investments in education. The functioning of markets will also have to be improved. Finally, one can conjecture that the current lack of other infrastructure such as roads, electricity, communications and so forth, must also conspire to reduce the impacts that can be garnered from irrigation alone. The paper's results enhance the case for multi-sectoral approaches for development projects generally.

These findings have implications for Vietnam's future rural development. The results suggest that the poor, and poorly educated, will obtain systematically lower returns to investment given current circumstances. These circumstances include disparities in educational attainments that are correlated with poverty, the existence of important synergies between human and physical capital, and missing or poorly performing labor markets. In such a situation, the knowledge-poor will have lower returns to investment and they will also be income poor. As capital markets develop, resources will flow to the higher returns. So one can expect the transition to a market economy in Vietnam to be inequality increasing unless the inequalities in education are redressed or markets for skills are somehow made to perform better.

Do the paper's results imply that governments should only invest in irrigation infrastructure in high education—and likely wealthier—areas? Two arguments question that conclusion. First, governments are in the business of providing education. The fact that there are differences across groups implies a market failure that the government needs to correct. The second reason is that the areas with higher schooling attainments will be better positioned to engage in cooperative arrangements and privately provide for their water management needs. It is in the low education areas that the case for public intervention may be most compelling.

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Table 1: Adult education attainments in North and South Vietnam by poverty status in mean years (standard errors in parentheses)

	North		*South*	
	Poor	*Non-poor*	*Poor*	*Non-poor*
Head's years of primary education	4.52	4.55	3.88	4.03
	(.03)	(.03)	(.07)	(.06)
Other adults' years of primary education	2.72	3.43	0.95	1.49
	(.07)	(.12)	(.09)	(.11)
Head's years beyond primary	6.31	7.25	6.20	8.33
	(.13)	(.18)	(.31)	(.28)
Other adults' years beyond primary	3.80	5.61	1.86	4.04
	(.12)	(.22)	(.20)	(.26)

Table 2: Variable definitions and summary data

Variable	*Definition*	*Mean*	*Std. Dev.*
crop income	Net yearly household crop income, 1993 Dongs	2,282,069	2,391,173
sick	Dummy for household member being sick in last year	0.933	0.250
gender	Gender of household head	0.809	0.393
hhsvgs	Initial stock of household savings, 1993 Dongs	939,223	8,990,056
size	Size of the household	5.033	1.992
prop06	Proportion of household members who are 6 years and young	0.156	0.176
prop716	Proportion of h'hold members who are 7 to 16 years, inclusive	0.213	0.204
pfadlt	Proportion of household members who are female adults (17 +)	0.327	0.169
pmadlt	Proportion of household members that are male adults (17 +)	0.282	0.160
hed1	Years of primary education of household head	4.379	1.114
hed2	Years of post-primary education of household head	2.513	2.842
oed1	Years of primary education of other adult h'hold members (17 +)	6.872	5.372
oed2	Years of post-primary education of other adult members (17 +)	4.111	5.287
irrigated	Irrigated annual crop land area (m^2)	2,267.58	3,997.50
nonirrigated	Non-irrigated annual crop land area (m^2)	2,605.92	5,632.34
perennial	Perennial land area (m^2)	678.43	2,169.50
forest	Forest land area (m^2)	279.22	1,970.98
waterland	Water surface land area (m^2)	122.89	1,203.53
otherland	Other land area (m^2)	217.50	2,106.11
long term	Proportion of annual land which is long-term	0.20	0.380
auction	Proportion of annual land which is auctioned	0.023	0.092
private	Proportion of annual land which is private	0.227	0.341
sharecrop	Proportion of annual land which is sharecropped/rented	0.043	0.165
allocated	Proportion of annual land which is allocated	0.507	0.431
urban	Dummy variable for urban residence	0.057	0.231
nu	Dummy variable for the Northern Uplands region	0.183	0.387
rr	Dummy variable for the Red River Delta region	0.275	0.447
nc	Dummy variable for the North Coast region	0.178	0.383
cc	Dummy variable for the Central Coast region	0.090	0.286
ch	Dummy variable for the Central Highlands region	0.020	0.139
mk	Dummy variable for the Mekong River Delta region	0.20	0.40

Table 3: Crop Income Regressions

	Unrestricted Model		*Restricted Model*	
Crop income	*Coefficient*	*t-ratio*	*Coefficient*	*t-ratio*
urban	1,093,640	1.08	83,7371	1.25
sick	-31,8465.4	2.59	-317,534.3	2.61
size	81,451.7	2.12	67,405.6	2.61
prop06	-586,514.9	1.18	-42,9757.1	2.08
hed1	-468,646.3	2.69	-52,7229.5	3.12
hed1*hed1	67,862.6	2.66	76,644.0	3.13
oed1*oed1	-1,932.7	2.48	-1,566.7	3.22
oed2	21,023.8	1.24	27,026.3	2.85
irrigated	352.40	4.27	362.59	4.78
irr*irr	-0.0030	4.42	-0.0030	4.82
nonirrigated	238.40	3.81	206.72	8.20
nonirrig*nonirrig	-0.0036	9.60	-0.0034	10.63
perennial	-277.04	1.73	-238.17	2.11
perennial*perennial	-0.0097	6.43	-0.0099	7.10
forest	-372.88	1.35	-80.33	1.02
forest*forest	-0.0026	1.38	-0.0022	2.0
waterland*waterland	-0.0401	3.80	-0.0042	5.12
otherland	-611.27	1.22	-426.07	2.16
otherland*otherland	-0.0024	1.32	-0.0016	1.19
auction	1,116,555	2.54	1,048,419	2.62
private	325,505.5	1.49	215,568	1.50
allocated	470,198.4	2.10	337,486.1	2.07
hed1*irrigated	47.87	6.06	49.80	6.93
hed1*otherland	-113.39	2.58	-111.97	3.40
hed2*irrigated	-6.46	1.53	-5.10	1.46
hed2*perennial	21.90	2.53	25.85	4.09
hed2*forest	23.01	1.62	26.73	3.23
hed2*waterland	72.61	1.58	30.70	2.12
hed2*otherland	33.45	1.51	22.67	1.14
oed1*irrigated	20.74	8.03	20.74	8.58
oed1*nonirrigated	7.27	3.38	5.66	3.51
oed1*perennial	5.42	1.21	5.10	1.20
oed1*forest	-21.37	1.72	-12.80	3.20
oed1*otherland	-49.20	4.66	-39.95	4.48
oed2*irrigated	-4.179	2.18	-4.57	2.52
oed2*nonirrigated	1.741	1.04	1.990	1.34
oed2*perennial	-10.914	2.65	-10.694	2.76
oed2*otherland	33.814	4.0	25.259	3.60
size*irrigated	-35.991	6.94	-35.865	7.51
size*nonirrigated	4.639	1.13	7.243	2.22
size*perennial	52.933	4.62	51.712	4.79
size*forest	37.473	1.68	28.892	2.38
size*otherland	79.081	2.62	64.675	2.28
pfadlt*irrigated	-176.63	2.16	-189.17	2.55
pfadlt*nonirrigated	-137.02	2.07	-115.10	2.30
pfadlt*perennial	610.10	3.33	628.69	4.12

	Unrestricted Model		*Restricted Model*	
pmadlt*irrigated	-162.40	1.71	-142.17	1.70
pmadlt*perennial	289.39	1.92	290.70	2.63
prop716*irrigated	155.85	2.03	132.86	1.94
rr*irrigated	271.75	4.06	260.97	4.17
rr*forest	135.35	1.03	74.85	1.19
mk*irrigated	-67.71	1.94	-83.64	2.65
mk*perennial	-158.92	2.94	-147.73	2.95
nu*irrigated	255.81	3.47	241.34	3.43
nu*perennial	-199.58	2.27	-215.25	2.77
nu*otherland	434.86	1.20	361.41	5.02
nc*perennial	-218.53	3.02	-205.53	2.96
nc*otherland	528.01	1.39	480.14	3.09
cc*irrigated	-203.38	3.63	-211.93	3.97
cc*nonirrigated	-152.25	2.62	-147.69	3.03
cc*perennial	-228.68	1.26	-226.31	1.26
ch*irrigated	-973.79	1.66	-1,051.07	1.81
ch*nonirrigated	-134.37	2.65	-130.90	3.29
ch*perennial	310.57	4.37	326.09	4.96
ch*waterland	5,195.78	1.31	4,078.46	2.70
	Number of obs = 3049		Number of obs = 3049	
	F(233, 2815) = 19.06		F(183, 2865) = 24.04	
	Prob > F = 0.0000		Prob > F = 0.0000	
	R-square = 0.6120		R-square = 0.6057	
	Adj R-square = 0.5799		Adj R-square = 0.5805	
	Root MSE =1.5e+06		Root MSE = 1.5e+06	

Note: The restricted model results from the pruning of all variables with t-ratios less than 1 in the unrestricted model. The unrestricted model also contained the following variables: demographic composition variables, pmum716, pfadlt, pmadlt and interactions with land variables; education variables: hed2, hed2^2, oed1, oed2^2 and interactions with land; land: waterland and interactions between types of land and regions; long term, sharecrop.

Table 4: Marginal Effect on Net Crop Income Allowing for Interaction Effects

		Unrestricted model		*Restricted Model*	
Variable		*Marginal effect on net crop income*	*t-ratio*	*Marginal effect on net crop income*	*t-ratio*
Irrigated annual land	Dongs/m^2	485.7	16.1	482.3	17.9
Non-irrigated annual land	Dongs/m^2	199.9	8.1	218.8	16.3
Perennial land	Dongs/m^2	212.7	4.1	233.9	6.7
Forest land	Dongs/m^2	87.2	1.9	63.3	1.8
Water surface land	Dongs/m^2	-864.9	0.1	157.3	3.3
Other land	Dongs/m^2	104.2	1.2	23.5	0.4
Household size	Dongs/person	59,065.9	2.0	62,154.9	2.8
Prop female adults	Dongs/% point	-2,366.5	0.1	78,456.6	0.4
Prop male adults	Dongs/% point	-1,165.1	0.2	-125,228.9	0.6
Prop aged 7-16	Dongs/% point	1,041.6	0.2	301,322.2	1.9
Primary ed (head)	Dongs/year	191,875.8	3.0	232,762.7	4.1
Ed > primary (head)	Dongs/year	38,584.9	2.0	22,132.4	2.3
Primary ed (other adults)	Dongs/year	35,094.1	2.5	31,466.8	4.7
Ed > primary (other adults)	Dongs/year	22,195.7	1.8	20,094.3	2.6
Mean yearly crop income		2,282,069		2,282,069	

Note: Marginal effects are evaluated at mean points.

Table 5: Complementarities Between Land, Irrigation, and Education

Education scenario	*Marginal effect of irrigated land on crop income*	*Marginal effect of non-irrigated land on crop income*	*Net marginal effect of irrigation on crop income*
Baseline	485.7	199.9	285.8
All education levels increased (+ sd)	586.3	244.9	341.4
All primary education increased (+ sd)	627.0	239.4	387.6
Primary education of household heads is full 5 years	515.4	200.3	315.1

Note: Primary education of household head is increased to maximum possible primary education: 5 years. Other increases are equal to 1 standard deviation of specific variable. These results are based on the unrestricted model.

Table 6: Marginal Benefit Function from Irrigation

Variable	*Effect on marginal benefit*	*t-ratio*
Intercept	114.0	1.24
Irrigated land	–0.006	4.42
Non-irrigated land	0.0072	9.60
Household head primary education	47.87	5.56
Household head other education	–5.131	1.07
Other adult primary education	13.472	4.69
Other adult other education	–5.92	2.57
Household size	–40.63	7.04
Proportion of female adults	–39.61	0.44
Proportion of male adults	–100.14	1.00
Proportion of children 7 to 16	148.1	1.94
Red River	315.81	3.05
Mekong Delta	–72.08	3.44
Northern Uplands	274.64	1.63
North Coast	98.67	1.14
Central Coast	–51.13	0.75
Central Highlands	–839.42	1.41

Note: Each number represents the effect of that variable (evaluated at the mean value) on the marginal benefit of irrigating one unit of non-irrigated land. These results are based on the unrestricted model.

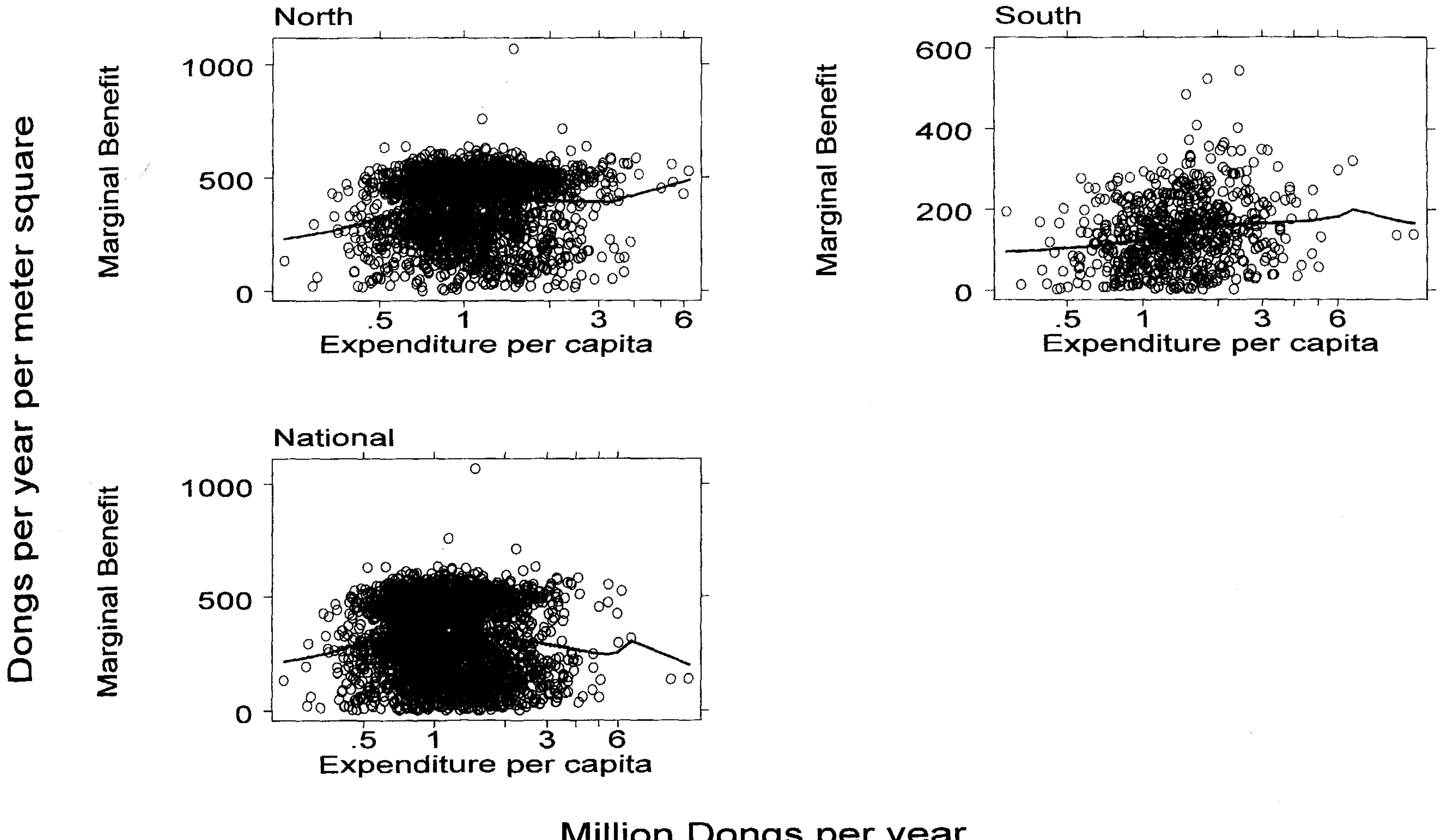

Figure 1. Marginal Benefits by Area

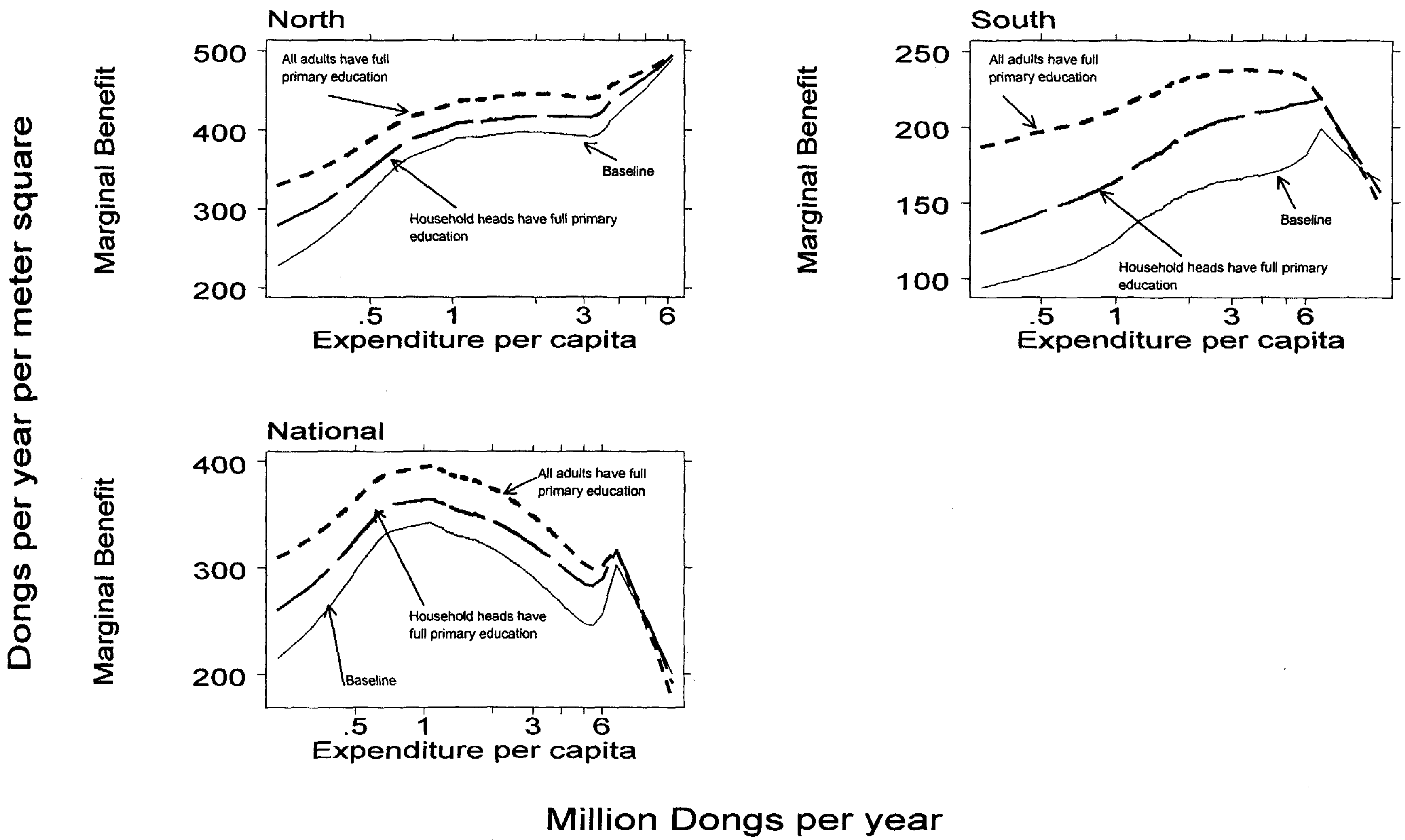

Figure 2. Impact of Education on Benefits from Irrigation

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